PATENT SPECIFICATION

793,402

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COMPLETE SPECIFICATION

Improvements in or relating to Cold Pressure Welding

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2., a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to apparatus for and methods of cold pressure butt welding together tubular parts of cold pressure weldable metal or metal alloys.

It has already been proposed, as described, for instance, in British Patent Specifications Nos. 689,927 and 728,139 to butt weld two parts by cold pressure welding, and an object of the present invention is the provision of apparatus for cold pressure butt welding metal tubing, insuring proper alignment of the work-pieces and substantially eliminating lateral movement or skidding during welding and to overcome other drawbacks and difficulties encountered in the cold pressure butt welding of metal tubes.

According to the present invention, apparatus for uniting by cold pressure welding two tubular parts of cold pressure weldable material and of similar cross-sectional dimensions in a butt joint with the tubular parts co-axial, comprises an internal supporting member and an external clamping member individual to each tubular part, and guide means for constraining the internal supporting members and external clamping members to move co-axially together upon the application of pressure to effect butt welding of the tubular parts.

In order that the invention may be clearly understood, reference is now made to the accompanying drawings which illustrate examples of welding apparatus and methods according to the invention and in the drawings:—

Figure 1 is a side view of two mandrels slidable upon a common guide rail rod, the parts being in section to illustrate flash forming relief surfaces;

Figure 2 is a section through two composite die members, including the mandrels of Figure 1, and with two sections of tubing of similar cross-sectional dimensions to be joined mounted therein, the outer dies being split tapered dies with the interface perpendicular to the plane of drawing;

Figure 3 is a section similar to Figure 2, with the dies closed and a butt weld formed;

Figure 4 is a section taken along line 4—4 of Figure 3;

Figure 5 is a sectional view of a modified tooling particularly adapted to workpieces which will not permit central rail guide means, the tooling having a bridging guide device to interconnect the dies as they close;

Figure 6 is a sectional view taken along line 6—6 of Figure 5;

Figure 7 is an illustration of abutting face configuration of an aluminium and a copper tube to predispose the tubes to flow equally into the weld flash;

Figure 8 illustrates schematically and in greater detail an improvement in butt welding two members of different hardness, the members being shown in their position prior to welding;

Figure 9 shows the members of Figure 8 in an intermediate position during the welding cycle; and,

Figure 10 shows the members of Figure 8 in the final welding position.

Referring now to the drawings particularly Figures 1 to 4 thereof, there is illustrated butt welding apparatus having two composite dies 10 and 11 composed of tapered outer dies 12 and 13 with inner plug dies as mandrels 14 and 15 associated therewith.

As previously indicated, it is necessary to provide for almost perfect alignment of the butt end of tubular members in order to achieve a good weld. During the welding operation there are forces operating in a lateral direction which tend to move the abutting surfaces out of proper relationship, even

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when originally perfectly aligned. Accordingly, the inner or plug dies 14 and 15 are illustrated as being slidably mounted upon a guide rail rod 20 extending through the axis of the plug dies 14 and 15. In Figure 1 both dies 14 and 15 are slidably mounted upon the rod 20 and a composite nut and lock nut 21 serve as a retainer to keep the slidable plug dies upon the rod. By the provision of a true rod 20, the dies 14 and 15 will be held to an exact relative movement, and accordingly will hold any tubular members carried over the dies in a fixed relative path.

The outer dies 12 and 13 are preferably made in tapered form in order to conveniently fit into suitable sockets in carriages 16 and 17. The sockets are indicated by the reference characters 18 and 19. Thus, as force is exerted upon the face of the dies, they will be seated into the sockets. The outer dies 12 and 13 are split, and accordingly such movement into the sockets will cause the dies to close down to grip a workpiece positioned therein. Any suitable driving mechanism may be employed to move the carriages 16 and 17 in a work path toward and away from one another provided that such driving means produces a sufficiently intense force which will maintain the workpiece fixed in contact, and continuous in its movement in order that the metal flow once started will be continuous and severe in nature.

The plug dies 14 and 15 are carried centrally of the split outer dies 12 and 13 respectively, as pictured in Figure 2, and therefore the outer surface of the plug dies and the inner surface of the outer dies define an annular space in which tubes 24 and 25 may reside. As the welding action begins, the tapered outer dies will close down upon the space and thus will cause a tight gripping force to be exerted upon the tubes 24 and 25.

According to the normal practice of cold pressure welding in which the high pressures cause the continuous and severe flow of metal, a provision must be made for a place for the metal to flow. It is known that the value of a given weld will be determined in large measure by the unrestricted flow of metal either sideways away from the weld point or into the thickness of the metal when welding sheet and it has been found that many of the principles with regard to welding sheets and similar overlapping structures cannot be applied exactly to the butt welding of tubular parts. Moreover, it has been discovered and fully substantiated that the interfaces must be pressed together very intensely over a surface which is not only in movement, but which is fixed in contact and is expanding in area. Accordingly, face recesses 22 and 23 provided on composite die 10 illustrate a suitable recess in the die surface which will permit metal from the tubes 24 and 25 to expand and move as specified. It has further been discovered that acceptable welds require that the metal flow from the centre outwardly in both directions. Welding of tubes may be likened to the welding of a flat sheet except that the sheet is rolled into tubular form. Accordingly, in the joining of the tubes 24 and 25 the butt face ends 26 and 27 are squared as perfectly as possible with the body of the tubes, and if necessary made free of oxides and other contaminants by scratch brushing or machining away part of the end surface, such as by cutting the tube to produce a fresh end. The end of the tubing is then allowed to project beyond the face of the composite dies. Therefore, as the dies 10 and 11 close together, the surfaces 26 and 27 will be first to contact. An acceptable degree of perfection in this contact is provided by the insertion of the plug dies 14 and 15 into the ends of the tubular members as illustrated in Figure 2.

After contact of the ends 26 and 27, the force must be severe and continuous. Such force will cause the metal to deform and begin to flow, and consequently will produce extreme lateral forces. However, it has been found that the rod 20 will hold the plug dies 14 and 15 rigidly in their prescribed position, and consequently the tubular members will also be confined to acceptable limits of movement.

The closing of dies 10 and 11 is stopped by face to face contact between the dies, and the lateral flow of the material of the tubes is permitted by the provision of the face recesses such as the recesses 22 and 23 in die 10. Such flash is illustrated by the outer flash 28 and the inner flash 29, best seen in Figure 3 of the drawing.

The amount of metal required to flow as a flash will be determined by the material being welded and by the cleanness of the face surfaces 26 and 27, among other things. Accordingly, the projection of the tubular members 24 and 25 from the faces of the dies 10 and 11 may be determined by calculation or experience, or both, and provided by the use of suitable stop means while initially positioning the tubular members. Furthermore, the faces of the dies 10 and 11 which contact and stop the welding movement may be relieved to cause a greater flow as the actual welding surfaces wear. In the Figure 3 the dies appear to be in contact adjacent the surface of the tubes at the base of the weld flashes 28 and 29 . Actually there is a slight degree of clearance at these points which cannot be faithfully illustrated in a small drawing without undue exaggeration. However, the degree of clearance is so slight that the flash may be removed manually with a pair of pliers in most instances and the inner flash is removed when the rod 20 and plug dies 14 and 15 are withdrawn.

In Figure 5 there is illustrated apparatus for uniting smaller size tubes and workpieces in which the centre mandrel is not sufficiently large to provide space for a central guide rail.

In Figure 5 split and tapered holding dies 31 and 32 are driven through a work cycle path toward and away from one another by means of carriages 36 and 37. Either manual or power driving force may be employed to operate the carriages 36 and 37. Inasmuch as the driving source is not a part of the present invention, such source of driving power is not illustrated.

In the modification of Figure 5, the dies 31 and 32 are provided with annular shoulders 33 and 34, respectively, on the forward ends thereof. These shoulders provide guide surfaces and are proportioned to fit internally within an annular ring 35. Ring 35 therefore serves as a bridging guide rail in co-operation with the guide surfaces provided by the shoulders 33 and 34. In the illustrated form of the tooling as shown in Figure 5, the annular bridge member 35 is a separate member from either of the die devices, and the shoulders 33 and 34 enter into the internal dimension of the annular ring 35 early in the closing movement of the dies and are thereafter accurately guided toward one another in a fixed path, and will successfully resist lateral forces produced by the welding operation.

In order to further aid the accurate alignment of the dies, a pin 38 carried by carriage 36 bridges the gap to the carriage 37, and is slidably carried in a bushing 39 therein.

Figure 5 further illustrates the preferred practice in the welding of small size tubing. Tubes 40 and 41 are provided with internal plug dies 42 and 43, but are not provided with a guiding rod such as the rod 20 shown in the Figures 1 through 4. Thus, the Figures 1 to 4 illustrate an axial interconnecting bridge means, whereas the Figures 5 and 6 illustrate bridge connecting means other than the axial bridge. In larger size tubing or tubing which requires extreme accuracy both alignment systems may be employed.

It has been found that metal workpieces of different hardness or flow characteristics may be welded by predisposing the butting ends to co-operate in retarding the speed of flow of the workpiece having the greater flow tendency. Thus, as illustrated in Figure 7, the welding of a copper tube and an aluminium tube is set forth as an example. In this example the copper tube is provided with a concave abutment end 44, whereas the aluminium tube which has the greater flow characteristic is provided with a convex end 45. Therefore the convex end will be partially enveloped by the copper tube which has the lesser flow characteristic. The retarding of the aluminium tube and the provision of a thin section of the concave end 44 to aid in the flow of the copper tubing permits a substantially balanced flow. Heretofore attempts to weld materials of such different flow characteristics has resulted only in the softer of the metals sliding over the surface of the harder metals and completely failing to weld. As pointed out before, it has been discovered that welding requires constant contact over an expanding area, but not a sliding of one metal over the other.

In Figure 7, welding of copper to aluminium has been chosen as the example, but this is by way of example only. Any metals which are weldable by this process, and which have differing flow characteristics, may be balanced as to flow characteristics by this method and caused to produce a perfect and acceptable weld. Thus, two aluminium tubes of different hardness and flow characteristics may be improved in weldability by this method.

It has also been found that the welding of tubes requires flash formation both to the interior of the tube as well as to the exterior of the tube in order to produce the necessary expansion of area with constant contact. Furthermore, there are instances in which it is desirable to completely block off the interior of the tube. An example of such instance is in the union of dissimilar metals which might have a tendency to corrode. Such blocking of the interior of the tubing aids in blocking moisture from intimate contact with the interface between the metals. Accordingly, in the preferred embodiment of the dies as illustrated, relief surfaces 46 and 47 are provided in the face of the dies 31 and 42, respectively, around the periphery of the cavity wherein the tube members are held. The surface 47 begins at the contact with the workpiece and recedes symmetrically therefrom in order to provide uniform relief surfaces around the interior of the tube.

A flash is produced as the workpieces are pressed together, and this flash is uniformly directed in a lateral direction, but is substantially pinched off at the end of the operation by the close proximity of the most forward portions of the dies at the junction of the workpiece surfaces. Accordingly, the flash may be easily stripped from the surface of the workpiece, and the outer diameter of the completely joined workpieces will be substantially the same as the original work pieces.

Referring now to Figures 8 to 10, the numerals 50 and 51 represent schematically two tubes to be welded and consisting of metals of different hardness, as indicated by the closeness of cross-hatching lines, such, as for instance, copper for the member 50 and aluminium for the member 51. Both tubes have their end faces precleaned to remove surface oxide and other contamination and

shaped to provide a convex and concave surface. The particular workpieces are not necessarily shaped to interfit, but rather are shaped to provide the best relative influence. In the instance illustrated a free space or cavity 56 remains between the pieces in the abutting position by forming the end face of member 51 with a slightly convex surface 54 and forming the end face of member 50 with a groove or concave surface 55. As indicated in Figure 7, the bottom of the concave surface 55 may have a radius at the bottom equal to a quarter of the effective projection A and the other surface a radius equal to the projection A. The members 50 and 51 are held or gripped by suitable welding dies 52 and 53 which are diagrammatically represented by sloping lines for clarity. Dies 52 and 53 may be split dies of the nature described above to which is applied the upsetting or welding pressure by means of a suitable hand tool or power press, in a manner well known and understood.

In order to control the proper amount of displaced or upset metal in the final welding position, Figure 10, the members 50 and 51 project from the dies 52 and 53 by predetermined distances A. As previously described the dies are shaped to abut and thus act as a stop means determining the end of the welding cycle. The faces of the dies are shaped to act as a means to confine or divert the upset metal in a radial direction to direct the interfacial metal flow and to cause merging and welding of the metals into a solid phase bond at the interface. In the drawing, the member 50 is shown projecting from its die face 53 by an amount greater by a distance A^1 than the projection A to take into account the effect of the groove 56. In general, the projection A is of the order of or approximately equal to the thickness or cross-sectional dimension of the members 50 and 51, and in the case of the harder member is equal to the distance from the die face to the bottom of the groove 56.

In order to obtain a substantially uniform or symmetrical weld, that is, with an upset or weld flash 58 produced with substantially equal flow of the harder and softer metals, respectively, the effective projection A of the member 50 of harder metal from its welding die 53 may be made slightly greater than the projection A of the member 51 from its die 52, to account for the free space or cavity 56 in the harder member. Since for best results the projection A is about equal to or of the order of the thickness of the members, the percentage increase of the projection of the harder member over the projection of the softer member can be easily determined from the size of the free space or cavity at 56.

In an arrangement of the type described, if an upsetting or welding pressure is applied to the members 50 and 51, the softer metal of the member 51 will at first be forced into the space or cavity 56, thus preventing or impeding its flow in the outward or welding direction and allowing the end of the harder member 50 to be initially upset and caused to flow outwardly in such a manner as to result in a meeting of the two metals, at an intermediate point during the welding cycle, in a substantially flat or slightly curved surface or interface 57. as shown in Figure 9.

Up to this point, that is, during the first stage of the welding cycle, the ends of the members have been deformed or forged to provide an interface 57 suitable for cold welding of the members during the subsequent stage of the welding cycle. As the welding pressure is continued and the interfacial flow of the metals is intensified and diverted in a substantially radial and outward direction by the die faces 52 and 53, respectively, the members flow to result in a final weld joint, as shown in Figure 10. As a result, by suitably shaping the end faces 54 and 55, as well as by the proper adjustment of the projections A of the members from the welding dies, it is possible to obtain a weld interface 57 which is slightly convex in respect to the harder member and concave with respect to the softer member, respectively, as shown in the drawing.

While a slightly convex end surface 54 is shown in Figure 8 for the softer member 51, it is understood that this surface may be substantially flat for some metals in order to secure the best results. Furthermore it has been found that successful butt welds can be produced where the amount of the softer metal in the weld flash 58 exceeds and overlaps the harder metal, in the manner shown in Figure 10, by proper control of the relative projections A of the members from their respective die faces prior to welding. However, under no circumstances may the excessive metal and the overlapping be accompanied by interfacial slipping.

With regard to the cold butt welding of tubular members of dissimilar metals such as copper and aluminium, a cold pressure welding process as described above has substantial advantages over previously known methods of welding dissimilar metals which used substantial amounts of extraneous heat, either below or above the fusion temperatures of the metals, for effecting a welded joint. In such heat welding methods, mixtures of the dissimilar metals in the form of the eutectic alloys of the metals, and also in the form of intermetallic compounds, are often formed. This is especially true with copper and aluminium. In most cases these eutectic alloys and intermetallic compounds are extremely brittle. This is particularly true of aluminium and of copper. These brittle compounds form at the interface area very rapidly under the heat of flash

or fusion welding. They form an extremely brittle layer in the weld area which appreciably lessens the strength of the weld and greatly increases the tendency for the weld to break under the slightest shock condition.

In using the cold pressure welding method with dissimilar metals, no appreciable heat is generated or applied during the welding, and, therefore, no such brittle alloys or compounds can be formed as a result of the welding process. In fact, since cold pressure welding is dependent upon drastic metal flow between pieces of deformable metal, it is impossible that such brittle compounds could either be generated or could remain in the welding area. They would be pushed out by the drastic metal flow.

It is true that such brittle alloys or compounds will form in a cold pressure welded joint, of, for example, aluminium and copper, if the welded joint is heated to a sufficiently high temperature for a sufficient length of time. However, it has been found that since there is no initial formation of such a brittle alloy or compound in the making of the weld, that such welds will stand a higher heat and for a longer time before an amount of brittle material appears, in comparison to such joints when made by flash or other heat welding.

It appears that in the heat welding of such joints, for example copper to aluminium, that initial or "seed" crystals of the brittle eutectic or intermetallic compounds are formed and promote the growth of additional amounts of such materials as the welds are heated. It has been found that in the case of cold pressure welded joints this growth is much slower under equal heating conditions, presumably due to the absence of the "seed" crystals in the weld interface.

Presumably because of the work hardening of the material in such welds as copper to aluminium at the interface, it has been found that the strength of such welds is increased slightly by applying heat after the weld is made. It has been found that for copper to aluminium, heating to 650 degrees for three minutes and quenching in water effects a strengthening of the weld over the strength immediately after it is made. A longer time at less heat is also effective.

What we claim is:—

1. Apparatus for uniting by cold pressure welding two tubular parts of cold pressure weldable material and of similar cross-sectional dimensions in a butt joint with the tubular parts co-axial, comprising an internal supporting member and an external clamping member individual to each tubular part, and guide means for constraining the internal supporting members and external clamping members to move co-axially together upon the application of pressure to effect butt welding of the tubular parts.

2. Apparatus as claimed in Claim 1, wherein the front faces of the internal supporting members and external clamping members are recessed away from the region where the butt joint is made to permit the lateral flow of material at welding both radially inwards and radially outwards.

3. Apparatus as claimed in Claim 1 or Claim 2, wherein surfaces are provided on the front faces of the external clamping means which surfaces engage one another at the end of the welding movement.

4. Apparatus as claimed in Claim 1, 2 or 3, wherein the guide means comprises a rod upon which one or both of the internal supporting members slide.

5. Apparatus as claimed in Claim 1, 2 or 3, wherein the guide means comprises an annular ring engaged by co-axial annular shoulders on the external clamping members.

6. Apparatus as claimed in Claim 1, 2, 3 or 5, wherein the guide means comprises a pin arranged parallel to the internal supporting and external clamping members, the pin being mounted in a carriage supporting one internal supporting member and one external clamping member, and sliding in a similar carriage for the other pair of members.

7. A method of uniting by cold pressure welding two tubular parts of cold pressure weldable material and of similar cross-sectional dimensions in a butt joint with the tubular parts co-axial, wherein the tubular parts are held accurately in alignment and their ends butted together whilst providing both internal and external support for the tubular parts.

8. A method as claimed in Claim 7, wherein the butting ends are pre-shaped to assist welding.

9. A method as claimed in Claim 8 and for welding two tubular parts of dissimilar flow characteristics, wherein a concave abutment surface is provided on the end of the tubular part having the greater resistance to flow and a convex abutment surface is provided on the end of the tubular part having the lesser resistance to flow.

10. A method as claimed in Claim 7, 8 or 9, wherein the weld area is heated after welding.

11. A method as claimed in Claim 10, wherein the weld area is quenched after heating.

12. A method of or apparatus for pressure welding substantially as hereinbefore described with reference to the accompanying drawings.

For the Applicants,
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Chartered Patent Agent.

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793,402 COMPLETE SPECIFICATION
3 SHEETS

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SHEET 1

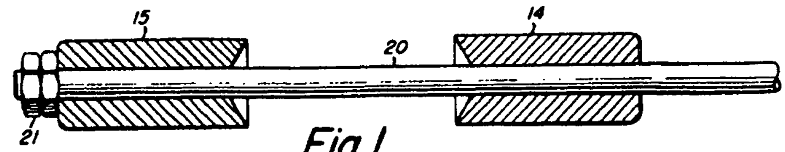

Fig. 1

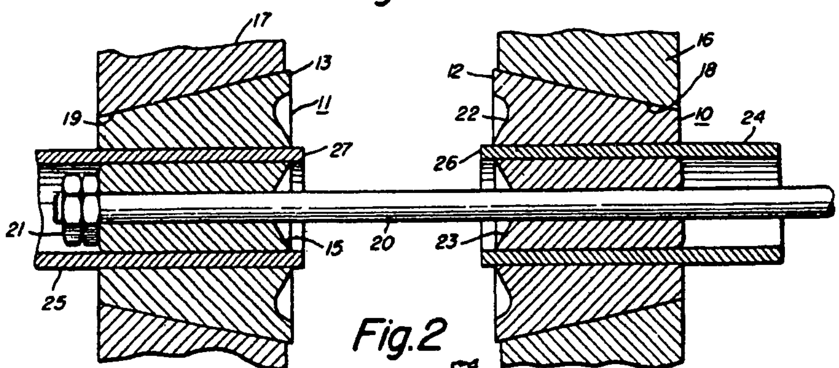

Fig. 2

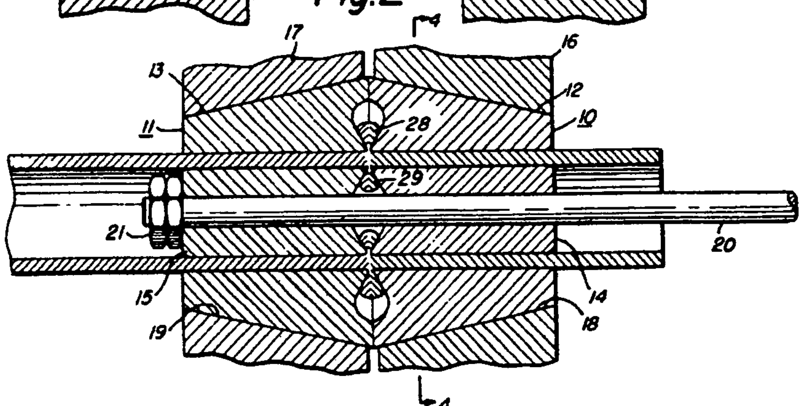

Fig. 3

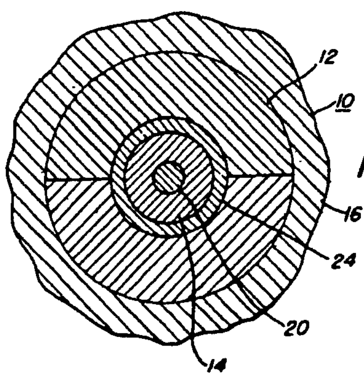

Fig. 4

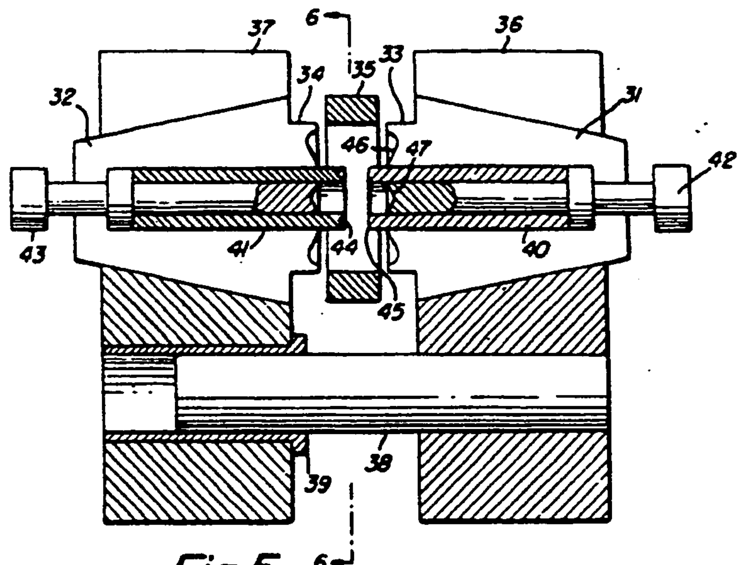

Fig.5

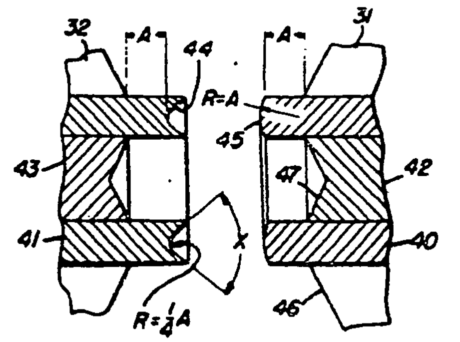

Fig.7

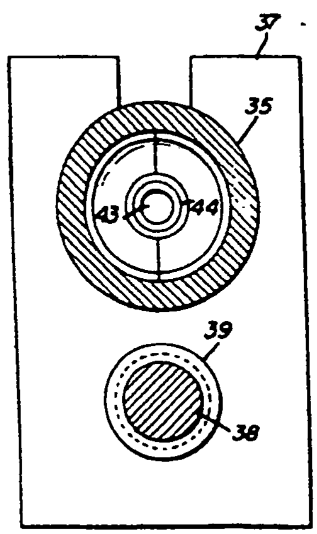

Fig. 6

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SHEETS 2 & 3

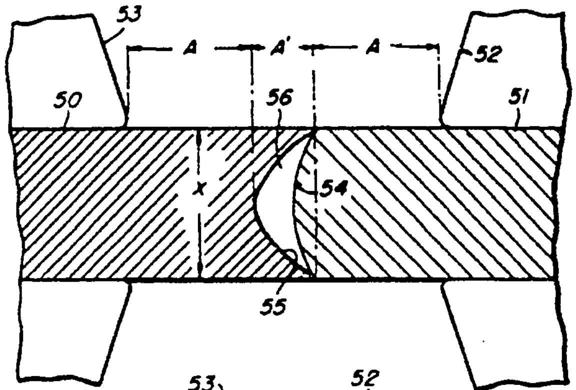


Fig.8

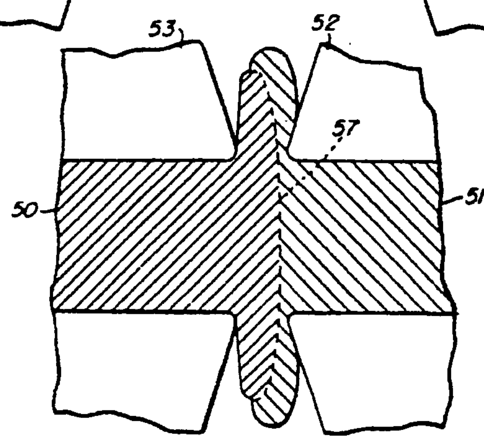
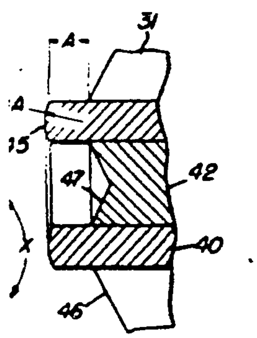


Fig.9



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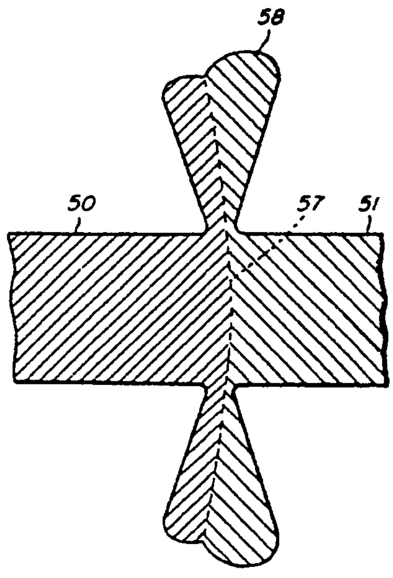

Fig.10

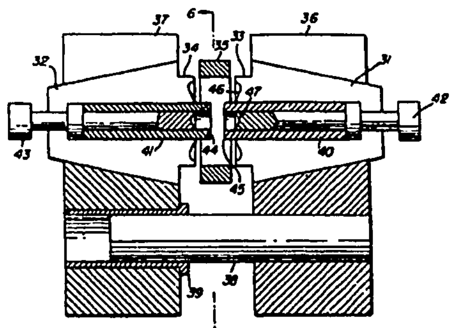

Fig.5

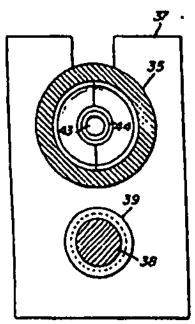

Fig.6

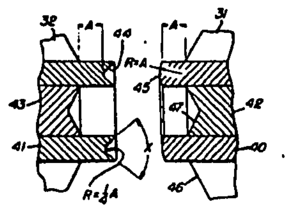

Fig.7

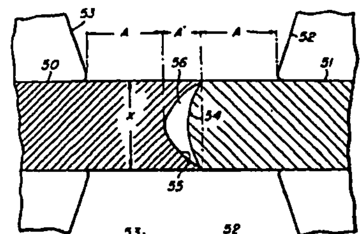

Fig.8

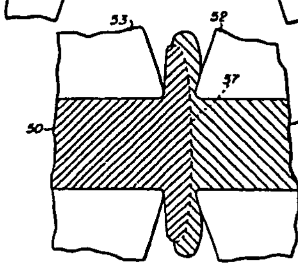

Fig.9

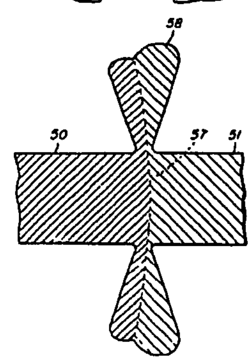

Fig.10